Integration of YOLOv10 with Edge Computing: Design and Application Research of a Non-Intrusive Fatigue Monitoring System

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ABSTRACT

Nowadays, with the increasing amount of time students spend studying and staring at the electronic screen, the phenomenon of low concentration, accumulated fatigue, and even damage to physical health and mental health has become very common. Compared with traditional learning aids, which are mostly based on manual check-in or wearable devices, they have many obvious disadvantages, such as subjective data collection and large interference. This paper introduces "EduHoot", a non-invasive learning fatigue monitoring system developed using YOLOv10 and the LicheePi edge computing platform. The system uses visual recognition technology to identify students 'facial behavior patterns in real-time and then realize the local non-intrusive fatigue detection and personalized feedback. Finally, the paper establishes an intelligent protection system for "learning health" and puts forward the system architecture, core technology, design concept and development roadmap. Finally, the paper explores the application prospects and social value of smart education based on edge computing through educational technology and AI development trends.

KEYWORDS: *Learning Fatigue Monitoring; YOLOv10; LicheePi; Edge Computing; Smart Education.*

INTRODUCTION

Learning fatigue, a common phenomenon among students during prolonged study sessions, not only reduces academic efficiency but also negatively impacts cognitive functions and mental health[1]. Existing research indicates that this condition manifests not only as physical drowsiness but also as distractibility, impaired memory, and emotional fluctuations[2]. Under the background of the implementation of the "Double Reduction" policy and the digital education, improving learning efficiency and health management has become an important link in educational reform.

Existing learning assistance products are mostly divided into two main categories: wearable devices like EEG headbands and smart glasses, which, while offering high accuracy, remain expensive, invasive, and suboptimal in user experience, thus failing to gain widespread adoption; and self-regulation apps such as Forest and Pomodoro, which, despite being cost-effective and accessible, rely entirely on subjective user input and lack objective monitoring capabilities[3]. None of these two categories of products can meet the requirements of students in self-study learning scenarios such as library study rooms.

"EduHoot" is an innovative solution developed in this context. By integrating the YOLOv10 object detection model with the licheePi edge computing platform, the system delivers non-invasive and low-interference real-time fatigue monitoring and personalized feedback without requiring smartphones or computers. This breakthrough enhances privacy protection for learners while ensuring seamless adaptation to various educational scenarios.

1. Related Research

1.1. Learning Fatigue and Attentional Resources
In 1990, Posner and Petersen proposed the three-part model of attention systems: the orienting

system, alertness system, and executive control system. This framework highlights that attention relies on the brain's limited cognitive resources[2]. When learners maintain prolonged periods of intense focus, the efficiency of the alertness and executive control systems declines, leading to distraction, delayed responses, and emotional fluctuations[2].

1.2. Empirical Research on Long-Term Learning

In 2016, Sievertsen and colleagues conducted a study on standardized tests and found that students' performance declines significantly with extended testing duration, while brief breaks can partially restore their performance[4]. Similar research also indicates that prolonged classroom learning leads to increased subjective fatigue and reduced attention levels[3][5]. These experimental results show that it is necessary to monitor and correct the fatigue of learners in real time.

1.3. Methods for identifying learning fatigue

Current monitoring methods for learning fatigue are primarily categorized into two types: physiological signals and behavioral characteristics. The former uses physiological signals such as heart rate and EEG as monitored signals. Usually, sensors need to be worn on the body, which is rather cumbersome and inconvenient to popularize in a wide range. The latter focuses on external behaviors like facial expressions, eye movement trajectories, or head posture through visual technology, which is more suitable for natural learning environments[6]. Chen Meifen further proposed a multi-dimensional feature recognition method integrating emotions, body posture, and learning behaviors, emphasizing the importance of these comprehensive features in fatigue assessment[3].

1.4. Deep Learning and Target Detection Technology

In recent years, numerous studies have explored learning fatigue through multimodal behavioral pattern recognition. For instance, Wang Tingting investigated intervention mechanisms for learning fatigue using facial expression recognition, while Feng Yuhang developed a fatigue detection method based on multi-posture head pose fusion that significantly improved recognition accuracy[6]. While YOLO series algorithms are famous for their efficient object detection in the field of object detection, they have been widely used in face recognition and behavioral analysis. Long Zihan's enhanced lightweight model of YOLOv8s demonstrated computational efficiency with minimal performance loss, proving its viability for

deployment in embedded devices[7]. The upgraded YOLOv10 further achieves end-to-end high-efficiency detection, opening new possibilities for real-time learning fatigue identification[8].

1.5. Edge Computing and Privacy Protection

In educational environments, system real-time performance and user privacy protection are critical. Shi et al. emphasized that edge computing, by processing data locally, can effectively reduce transmission latency and enhance data security[9]. This provides robust technical support for the lichee-Pai-based EduHoot system.

2. Questionnaire Survey and User Needs Analysis

In order to fully reflect real user needs and make the "Banshu Ying" system design grounded in practical application scenarios, the project team carried out an online anonymous survey based on Wenjuanxing platform and finally obtained 152 valid questionnaires. The subjects were mostly middle school students (94%), including 68.42% of college students, 16.45% of postgraduates, 9.21% of senior high school students, and the rest were self-study students who were preparing for exams and workers. The sample composition demonstrates strong representativeness.

2.1. Learning Behaviors and Fatigue Status

Survey data reveals that over 70% (71.06%) of respondents spend more than two hours daily on study sessions, with 51.32% committing 2-4 hours and 19.74% exceeding four hours – indicating that intensive study has become the norm. Regarding fatigue frequency, 81.58% of participants reported experiencing fatigue or mental distraction "frequently" or "occasionally," while only 1.97% reported feeling "virtually no" fatigue.

Further analysis of the time of fatigue showed that 50.66% of the respondents felt tired after 30-60 minutes of study, and 28.29% felt tired within 1-2 hours, indicating that most learners have a short focus window and need external intervention mechanism to assist rhythm management.

2.2. Manifestations and Causes of Fatigue

Multiple-choice survey results indicate that "inability to concentrate" (76.97%) was identified as the most prevalent fatigue symptom, followed by "memory decline" (53.29%) and "excessive drowsiness" (45.39%). Additionally, "irritability" (39.47%) and "physical discomfort" (23.68%) also showed significant prevalence, demonstrating that fatigue is a multifaceted phenomenon involving multiple dimensions.

Regarding contributing factors, "insufficient sleep" (61.84%) and "prolonged continuous study sessions" (57.24%) were identified as the most critical causes, while "academic workload pressure" (55.26%) and "environmental discomfort" (50%) also played significant roles. Notably, "anxiety" (50%) was frequently mentioned, highlighting the crucial role psychological factors play in fatigue development.

2.3. User Perception and Coping Strategies

While fatigue is a widespread phenomenon, people's self-awareness remains limited. Only 34.21% of respondents said they "always notice" their fatigue state, while 48.68% reported "occasionally noticing" it. Another 17.1% admitted they find it "difficult to detect" or are "completely unaware". This highlights the necessity of automated monitoring systems.

When experiencing fatigue, respondents commonly adopt coping strategies such as "getting up to move around or fetch water" (57.24%), "using their phones or scrolling through short videos" (53.29%), and "relaxing with music" (42.11%). Notably, 22.37% of learners still choose to "push through and continue studying," reflecting an unhealthy tendency toward persistent effort among some individuals.

2.4. Technology Acceptance and Functional Preferences

73.68% of respondents said they were "very willing" or "willing" to try smart devices that do not need to be worn and automatically identify fatigue, while only 4.61% explicitly said they were "unwilling", indicating that the market has high expectations for non-invasive monitoring technology.

Analysis of reminder methods: diversified feedback format preferences. In real-time intervention mechanisms, "light vibration/visual alerts" (59.87%) emerged as the most popular choice due to their non-intrusive nature, while "automated study pause" (38.16%) was also recognized as an active intervention option. Notably, nearly half of users (49.34%) opted for "push notifications showing fatigue status charts", reflecting a significant demand for long-term data tracking and self-monitoring.

Privacy concerns remain the central focus for respondents. While 74.35% expressed "somewhat" or "strong" reservations about continuous camera monitoring, 76.97% showed "significantly" or "moderately" increased acceptance when assured that "all biometric processing occurs locally without image uploads." This demonstrates that localized data processing serves as a crucial factor in building trust.

In addition, 84.21 percent of respondents said they would check the study Daily and fatigue trend report "frequently" or "occasionally," and 34.21 percent were "very interested" in daily focus score trend charts, demonstrating the significant appeal of data visualization feedback.

### 2.5. Willingness to Pay and Market Positioning

Regarding pricing, 52.63% of respondents are willing to accept device prices between 100-300 yuan, while 26.32% prefer keeping it under 100 yuan. For subscription models, 45.39% agree with monthly fees below 10 yuan, and 47.37% prefer "trying free devices first before deciding to subscribe." This suggests that products should initially adopt a hybrid model combining "hardware subsidies + service subscriptions" to lower the barrier to entry.

3. System Design Concepts and Methods

3.1. Product Positioning and Goals

EduHoot is a learning health and focus management system for students at all levels of education, ranging from K-12 students to college students and exam review groups. The value of EduHoot lies in its use of deep learning technology based on visual recognition and behavioral modeling to help users manage their study routine and learn more efficiently.

3.2. Overall System Architecture
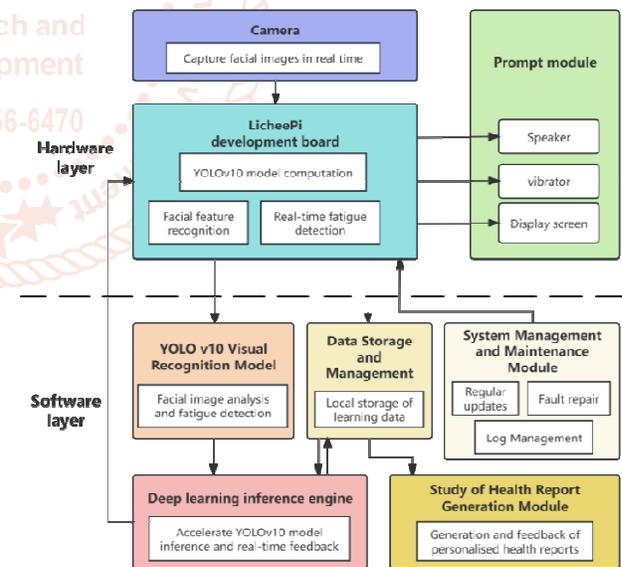
3.3. Core System Innovations

"EduHoot" has the following four core innovations in system design.

First, through the YOLOv10 algorithm and camera integration, EduHoot achieves non-intrusive and contactless fatigue detection—a breakthrough from traditional wearable devices. When users appear to be fatigued, EduHoot will actively trigger the user to take actions by voice prompts, screen prompts, or vibration reminders to adjust the rhythm of study.

This design ensures the objectivity of data, and does not disturb users' learning process. Currently, there is a strong demand for low-intrusion learning tools.

Secondly, all image data in EduHoot are processed on LicheePi edge computing devices and will not be uploaded to the cloud, which can completely avoid privacy risks. Through the "local inference" technology, not only does EduHoot comply with regulations such as Personal Information Protection Regulations, and improves users' trust in the system, but also EduHoot does not need to wear additional devices, which will not disturb users during the learning process, and thus helps to maintain the focus of learners.

Third, by constantly analyzing users' learning behavior (such as the time when the eye is closed and the change of head posture) and outputting corresponding feedback and study rhythm recommendations, EduHoot helps users improve their study habits little by little. EduHoot also outputs weekly learning health reports, and analyzes the trend of learning efficiency and fatigue. EduHoot establishes a whole process of traceable learning health management. Not only does this design meet the personalized education demand, but it also provides references for decision-making based on data for educational administrators.

Fourth, EduHoot's current architecture reserves space for the future development of other features such as emotion recognition and learning efficiency prediction, and EduHoot will become a comprehensive learning health management system. Based on the fact that YOLOv10 has high-efficiency detection capabilities and licheePi has edge computing advantages, the system shows technological foresight. EduHoot will continue to remain technically leading in the process of intelligent education.

4. Value Potential and Future Development
4.1. Commercial Value
With the acceleration of educational digital transformation, China's intelligent education market is in a phase of rapid expansion. According to the "China Artificial Intelligence Education Blue Book", the scale of China's educational smart

hardware market was approximately 43 billion yuan in 2023, and is expected to exceed 79 billion yuan by 2028, with a compound annual growth rate exceeding 13%. These figures indicate that the intelligent education market not only maintains high-speed growth globally but also demonstrates strong development potential within China[10].

EduHoot was designed to counter this educational phenomenon. Compared with other online feedbacks,

EduHoot has obvious advantages in the fields of feedback in real time, protecting students' privacy and making students not be disturbed while they are getting non-stop growing benefits. EduHoot's business model is as follows: selling hardwares and providing service are two inseparable parts. EduHoot hardware will be sold to student's family and school. EduHoot service includes every value-added benefit which will be continuously provided after selling hardwares to users, such as everyday progress report, fatigue trend analysis and data analytics.

Furthermore, EduHoot can also collaborate with other companies through B2B and C paths. EduHoot can deeply enter into school and online education platform or learning management system and expand the application scene to promote the large-scale application.

4.2. Social Value Embodiment
EduHoot enables users to further optimize their learning speed through individual management, enhancing their concentration and improving learning efficiency, while reducing fatigue and cognitive load caused by prolonged learning. EduHoot learning health report helps users to cultivate study habits and develop a routine in studying to maintain academic health for a long time. In order to protect user's privacy, all data processing occurs in local computing technology on licheePi. EduHoot will not upload data to the cloud. This design meets current privacy regulation and educational compliance requirements. Meanwhile, it enhances the security and reliability of education data governance.

4.3. Future Outlook
With the deepening development of educational digitalization, EduHoot is poised to gain widespread adoption in K-12 education, higher education institutions, and adult continuing education. Our products will gradually be applied in more learning scenarios, such as libraries, study rooms and smart classrooms in schools. In order to improve the functionality of the system, EduHoot will continue to optimize the lightweight performance and recognition accuracy of the YOLOv10 object detection algorithm, and explore more advanced and practical functions, such as emotion recognition and learning behavior analysis, to enhance the ability of EduHoot to detect and correct more complicated learning states. Finally, our company also hopes to cooperate with schools, online education platforms and health care institutions to popularize our products. On this basis, we will further improve the feedback mechanism of user use experience to ensure that the product can continuously improve in function according to user experience.

In the future, in addition to being a tool to improve students' academic efficiency, EduHoot hopes to become an advocate to help students maintain a healthy state. Therefore, in the future, EduHoot does not only want to help students improve their academic efficiency in the short term, but also wants to help students maintain their physical and mental health in the long term. EduHoot is also willing to be a practitioner who promotes the implementation of the "healthy learning" definition in the education industry.

5. Summary

This paper systematically proposes and demonstrates the design philosophy of the "EduHoot" learning fatigue monitoring system. Built on the YOLOv10 object detection model and licheePi's edge computing platform, the solution achieves seamless monitoring, real-time feedback, and localized processing, striking a good balance between privacy protection and adaptability to educational scenarios.

Based on the literature and survey results, this study aims to illustrate the learning fatigue's great influence on the individuals' concentration, cognitive ability, and academic achievement, and thus reveals the urgency and necessity of real-time monitoring and scientific intervention to fight against the learning fatigue. Compared with the existing systems, the innovations of EduHoot system are manifested in non-invasive detection, personal privacy protection, personalized feedback, and system scalability. Not only these innovations have demonstrated their commercial feasibility, but also the social value of educational equity and healthy learning environment is brought by them.

Although the research is still in its preliminary stage, the concept and framework proposed by this system provide a new idea and practical direction for the future of intelligent education and healthy learning management.

References

[1] Boksem, M. A. S., & Tops, M. (2008). Mental fatigue: Costs and benefits. Brain Research Reviews, 59(1), 125-139. https://doi.org/10.1016/j.brainresrev.2008.07.001

[2] Petersen SE, Posner MI. The attention system of the human brain: 20 years after. Annu Rev Neurosci. 2012; 35:73-89. doi:10.1146/annurev-neuro-062111-150525. Epub 2012 Apr 12. PMID: 22524787; PMCID: PMC3413263.

[3] Chen, M., & Lu, R. (2020). 在线学习疲劳状态识别方法及应用研究 [Research on the identification method and application of online learning fatigue state]. Journal of Shenzhen Polytechnic, 19(05), 23–29. https://doi.org/10.13899/j.cnki.szptxb.2020.05.005.

[4] Sievertsen, H. H., Gino, F., & Piovesan, M. (2016). Cognitive fatigue influences students' performance on standardized tests. Proceedings of the National Academy of Sciences of the United States of America, 113(10), 2621–2624. https://doi.org/10.1073/pnas.1516947113

[5] D'Mello, S., & Graesser, A. (2012). Dynamics of affective states during complex learning. Learning and Instruction, 22(2), 145–157. https://doi.org/10.1016/j.learninstruc.2011.10.001

[6] Feng, Y., Ye, H., Huang, W., Xu, Z., & Lin, J. (2021). 基于头部多姿态融合识别的疲劳检测与预警研究 [Fatigue detection and early warning based on multi-posture head fusion recognition]. Computer Knowledge and Technology, 17(13), 12–14. https://doi.org/10.14004/j.cnki.ckt.2021.1330

[7] Long, Z., & Xiao, X. (2024). 改进YOLOv8s的轻量化人脸识别算法 [Lightweight face recognition algorithm for improved YOLOv8s]. Information Technology and Informatization, (12), 201–204. https://doi.org/CNKI:SUN:SDDZ.0.2024-12-048.

[8] Wang, A., Chen, H., Liu, L., Chen, K., Lin, Z., Han, J., & Ding, G. (2024). YOLOv10: Real-Time End-to-End Object Detection. ArXiv, abs/2405.14458.

[9] Shi, W., Cao, J., Zhang, Q., Li, Y., & Xu, L. (2016). Edge Computing: Vision and Challenges. IEEE Internet of Things Journal, 3, 637-646.

[10] China Academy of Information and Communications Technology, & Zhuoshi Consulting. (2024). China artificial intelligence education blue book [Online report]. Retrieved from https://www.cninsights.com/report/10